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A 4～12GHz Wideband Balanced MIC Power Amplifier

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Abstract: A 4～12GHz wideband power amplifier, using a balanced configuration with a strip line Lange coupler, is designed and fabricated. This power amplifier shows a maximum continuous wave output power of 29.5dBm at 8GHz center frequency with an associated gain of 8.5dB and a gain flatness of +/−0.6dB in the 4～12GHz frequency range.

Key words: wideband; Lange coupler; microwave integrated circuit; balanced power amplifiers
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1　Introduction

With the development of wireless communications, telecommunications, date communications, and aerospace systems, the demand for transceivers has continually increased over the last decade. The wideband PA (power amplifier) is important in the transceiver. Langer couplers, losing match circuits, degeneration circuits, and TWAs (traveling wave amplifies) can be used as wideband power amplifiers. The differences among these circuits are shown in Table 1[1]. The balanced amplifier configuration is usually preferred in the wideband power amplifier because it presents several advantages[2] over the single-ended amplifier: (1) improvement of the 1dB compression point by 3dB, (2) inherent 50Ω input/output matching due to the presence of the coupler, and (3) redundancy, i.e., if one of amplifiers fails, the balanced amplifier unit will still operate with reduced power gain. So far, papers that have reported on other circuits using Lange couplers, such as the phase shifter[3] and mixer[4], are more common than on PAs. Recent results of a PA using a Lange coupler in China have shown a 18～20dB gain at 21～28GHz and an output 1dB compression power of 21dBm at 26GHz[5]. In this paper, we present the design procedure, fabrication, and characterization of a MIC PA with three times the bandwidth and a balanced amplifier configuration using a 4-finger Lange coupler.

Table 1　Differences between wideband circuits

	Langer coupler	Degeneration	Losing match	TWA
Bandwidth	Double	Several times	Several times	The most
Size	Large	Small	Middle	Middle
Match	Very good	Good	Bad	Good
NF	Lower	Middle	High	Lower
Tolerableness of the circuit	Big	Middle	Big	Middle
Cascade	Easy	Difficult	Difficult	Easy
Number of FET	Middle	Few	Few	Much
Linearity	Good	Very good	Middle	Good

2　Circuit design and simulation

2.1　Individual PA design

The wideband amplifier design is based on the use of a Lange coupler and the wideband match circuit for EPA090a, which was purchased from Excilics Semiconductor, Inc. The match circuit design was based on measured *S*-parameters for the device under biasing conditions corresponding to $V_{ds}=8V$ with $I_{ds}=140mA$. An Agilent ADS was used for simulating the individual match circuit and the simulation results are shown in Fig. 1.

Matching of individual devices was optimized for gain flatness characteristics rather than input and output voltage standing wave ratio (VSWR). Since the VSWR characteristics of a balanced amplifier are dependent on the coupler, this should

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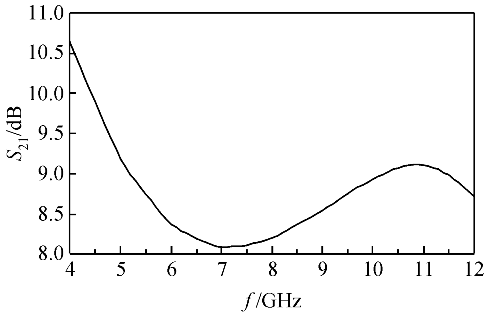


Fig. 1 Simulation results of the individual match circuit

not be a handicap for the circuit.

2.2 Four-finger Lange coupler design

The Lange coupler can be made of four or six coupler lines with interconnections and provide strong 3dB coupling. The initial analysis involves calculating the odd and even line impedances and then using Fig. 2 to read off the finger spacing and line widths[6]:

$$Z_{oo}/Z_{oe}=R=\frac{C}{(C+1)(N-1)}\left[-1+\sqrt{1+(1/C^2-1)(N-1)}\right]$$

where N = Number of coupler lines and C = Coupling coefficient = $10^{\mathrm{dB}/20}$.

Design for a 3dB coupler @ 7GHz using 4 coupled lines on Alumina ($\varepsilon_r = 9.8$),

$C = 0.7079$, $R = 0.29786$, $Z_{on} = 50\Omega$

$$\therefore \quad \sqrt{Z_{oo}Z_{oe}} = \frac{Z_{on}\sqrt{[N-1+R][(N-1)R+1]}}{(1+R)} = 96.272\Omega$$

$$Z_{oe} = \sqrt{\frac{(Z_{oo}Z_{oe})^2}{R}} = 176.4\Omega$$

$$\therefore \quad Z_{oo} = \sqrt{(Z_{oo}Z_{oe})^2 R} = 52.5\Omega$$

S/h was found to be 0.07 and W/h to be 0.1. The thickness of Alumina is $h = 0.38$mm, therefore $S = 26.6\mu$m and $W = 38\mu$m. The length

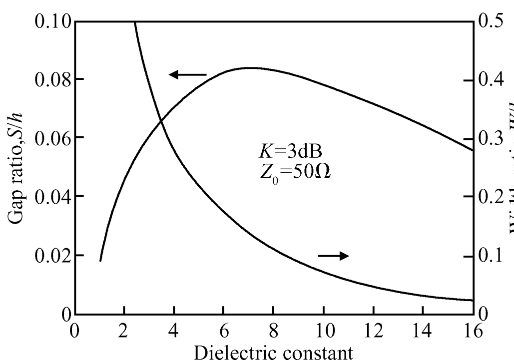


Fig. 2 Nominal 3dB shape ratio versus dielectric constant

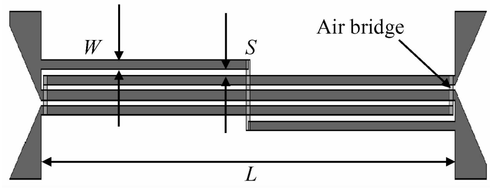


Fig. 3 Schematic of a four-finger Lange coupler

of the coupler lines will be: $\lambda_{air} = \frac{c}{f} = \frac{3\times10^8}{9\times10^9}$.

Thus, $L = \frac{\lambda_{air}}{4\sqrt{9.8}} = 3.4$mm.

The data was entered into the Lange model on the ADS2004A and was optimized. It was necessary to slightly increase the length to lower the frequency response and to narrow the spacing to increase the coupling so that there was slight overcoupling between the two output ports. The final data were $S = 25\mu$m, $W = 36\mu$m, and $L = 3.4$mm. The schematic of a four-finger Lange coupler is shown in Fig. 3. The frequency response of the two output ports and the input return loss of the Lange are shown in Fig. 4.

2.3 Balanced amplifier design

The wideband amplifier was designed based

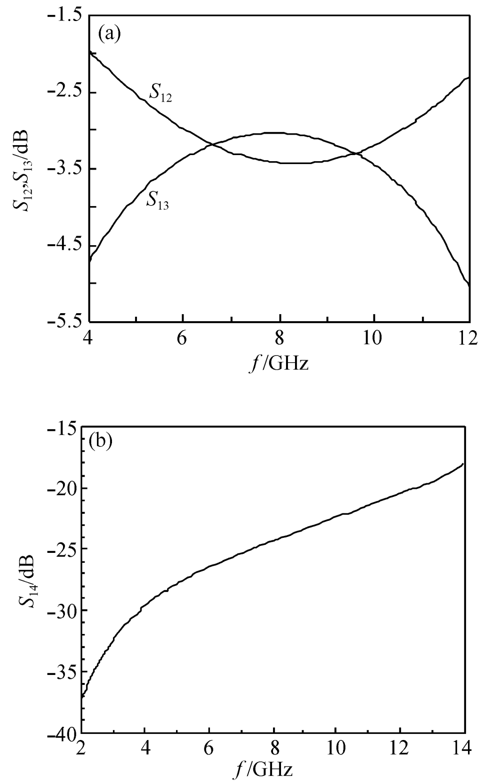


Fig. 4 Frequency response of the two output ports (a) and the input return loss (b) of the Lange

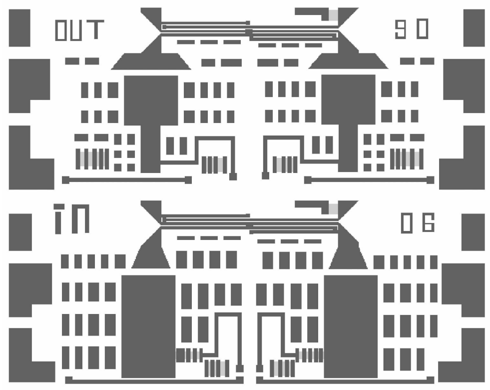


Fig.5 Layout of the input and output match circuit

on momentum simulation results of the Lange coupler in ADS and employed two identical individual PA connected to the coupler input and output. The isolated ports of the Lange coupler were terminated by on-chip thin-film 50Ω resistors. Figure 5 shows the layout of the input and output match circuit. Figure 6 shows the simulated associated gain together with input (dotted line) and output (solid line) VSWR of the balanced LNA. Compared with the individual PA simulation results, the Lange coupler improved the gain flatness. Noticeable performance improvement was observed for the input and output VSWR, which were found to be less than −5dB in the frequency range of 4～12GHz. This was due to the fact that the VSWR of the balanced amplifier is dictated by the coupler characteristics.

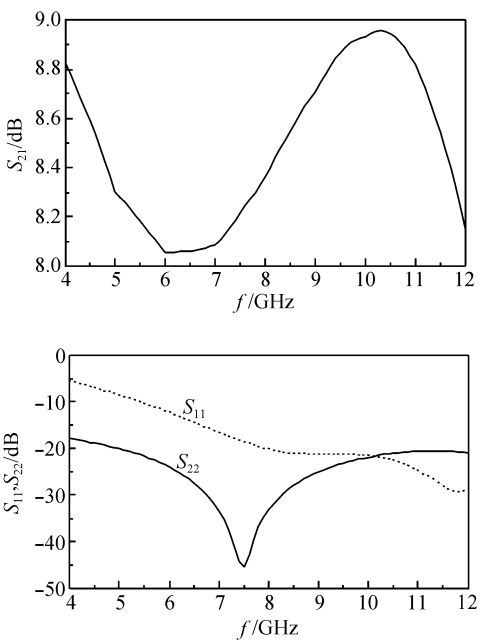


Fig.6 Simulation of the wideband PA

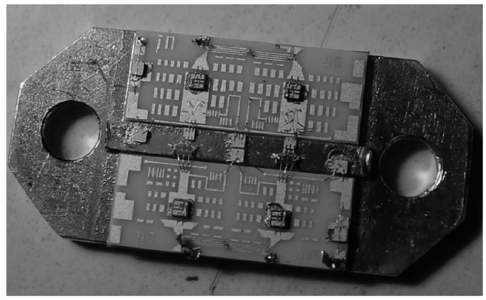


Fig.7 4～12GHz wideband power amplifier

3 Characterization of the wideband amplifier

A photograph of the fabricated chip is shown in Fig.7. The amplifier chip size is 6.4mm × 6.4mm. The measured small-signal gain (S_{21}), input (dotted line), and output (solid line) VSWR are shown in Fig.8 for bias points: $V_{ds} = 8V$, $I_{ds} = 280mA$. The measured gain was about 8.5dB with +/−0.6dB gain flatness and the input and output VSWR were found to be less than −5dB over a wide bandwidth of 4～12GHz. The input VSWR in low frequency are larger than in high frequency. For the gain flatness, we had to increase the input VSWR to pull the gain at the lower frequency. Thus, we also find the gain and the maximum CW output power at low frequency is less than it is at high frequency . The large - signal performance is

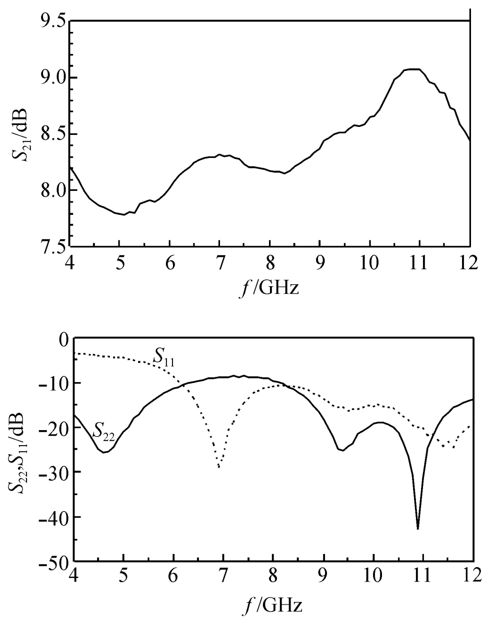
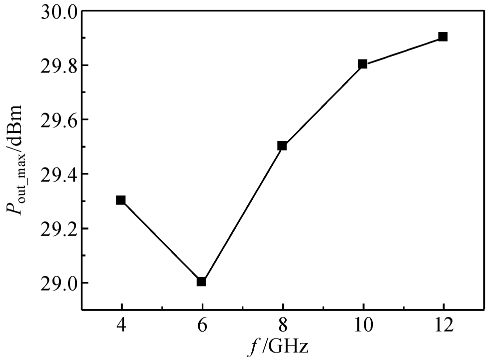


Fig.8 Measured small-signal performance of the amplifier



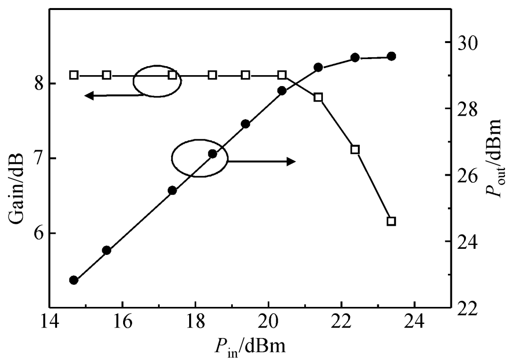


Fig. 9　Measured large-signal performance of the amplifier at 8GHz

shown in Fig. 9. The data were taken with V_{ds} = 8V and I_{ds} = 280mA. The maximum CW output power was 29.5 with +/−0.5dB flatness over a wide bandwidth of 4～12GHz.

4　Conclusion

A balanced MIC power amplifier using a Lange coupler was demonstrated with a 8.5dB gain and +/−0.6dB gain flatness over a broad bandwidth of 4～12GHz. The MIC PA shows a maximum CW output power of 29.5dBm with an associated +/−0.5dB flatness over a wide bandwidth of 4～12GHz.

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一个 4～12GHz 混合集成宽带功率放大器

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摘要： 设计研制了一个 4～12GHz 的宽带混合集成平衡功率放大器电路. 该平衡放大器由一个 4 指的微带兰格耦合器实现. 其输出连续波饱和功率在中心频率为 8GHz 时达到 29.5dBm，在 4～12GHz 频率范围内增益达到 8.5dB，增益平坦度为 +/−0.6dB.

关键词： 宽带；兰格耦合器；混合集成电路；平衡功率放大器

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